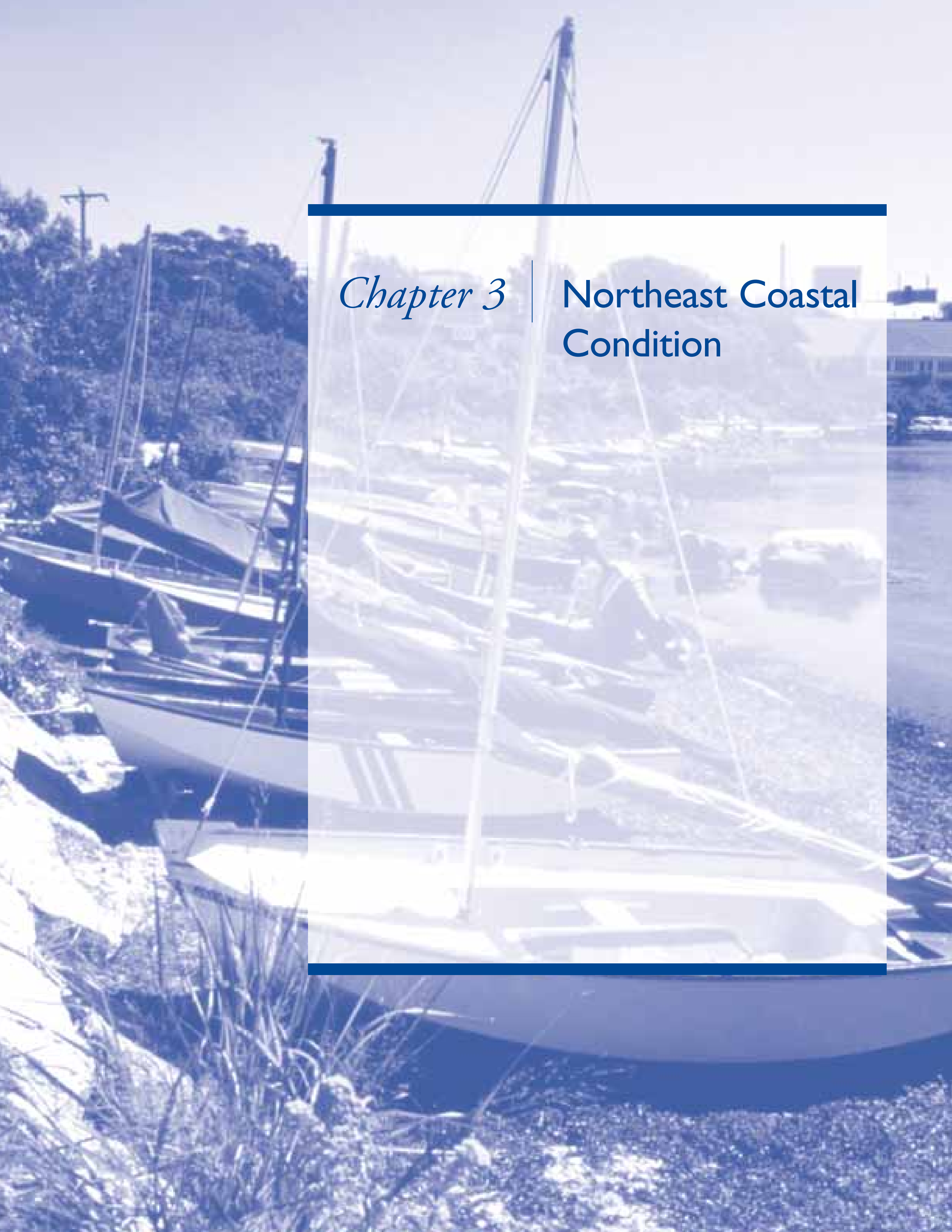


Chapter 3 | Northeast Coastal Condition

Northeast Coastal Condition

The overall condition of Northeast Coast estuaries is poor (Figure 3-1). Twenty-seven percent of estuarine area is impaired for aquatic life (poor condition), 31% is impaired for human use, and an additional 49% is threatened for aquatic life use (Figure 3-2). The Northeast Coast region contains diverse landscapes, ranging from mountains and forests and rocky coastal headlands in Maine to coastal plain systems in the Mid-Atlantic. The Northeast Coast is the most densely populated coastal region in the United States and includes the coastal waters of Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Delaware, Pennsylvania, Maryland, and Virginia (Figure 3-3). In the Northeast Coast region, the ratio of watershed drainage area to estuary water area is relatively small when compared to the ratios in the Southeast Coast and Gulf Coast regions. The by-products of past and current human activities in Northeast Coast watersheds are washed to the sea, affecting coastal conditions in the region. The highest levels of sediment contamination are found in depositional environments near urban centers, reflecting current discharges and the legacy of past industrial practices.

Anthropogenic nutrients delivered by rivers to the coast come from a variety of sources. In New England, nutrient inputs from agricultural activity are relatively small. Much of the nutrient delivery to the coast in the nonurban areas of northern Maine results from atmospheric deposition onto watersheds (Boyer et al., 2002).

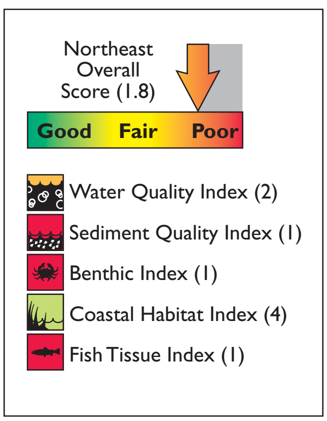


Figure 3-1. The overall condition of Northeast Coast estuaries is poor.

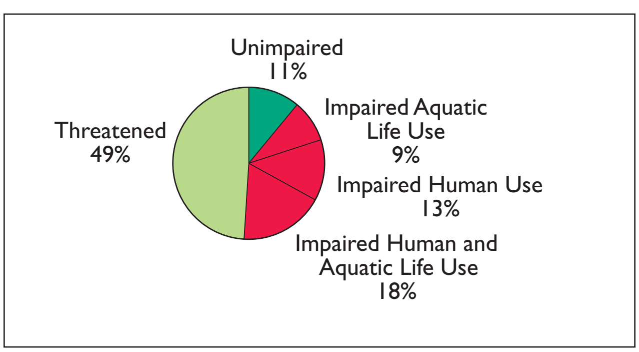


Figure 3-2. Northeast Coast estuarine condition (U.S. EPA/NCA).

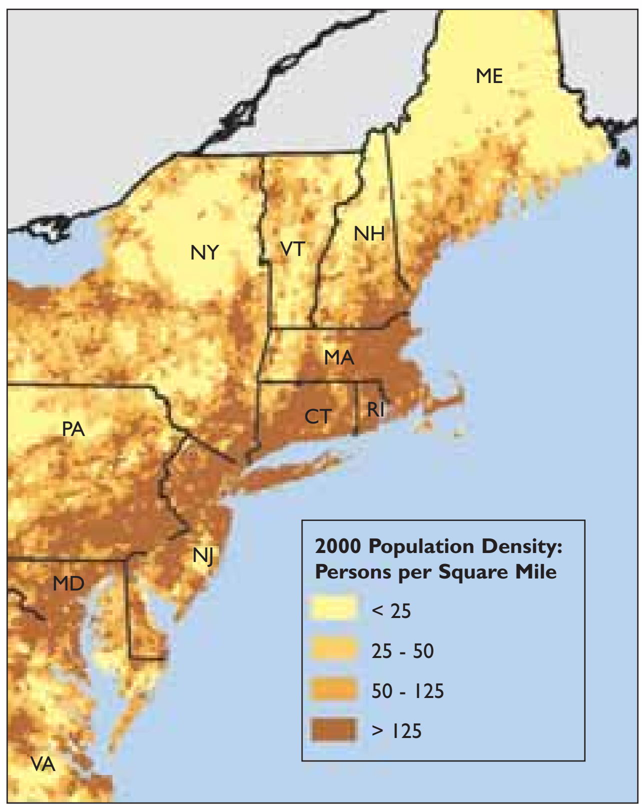


Figure 3-3. Human population density by county for watersheds that drain to the Northeast Coast (U.S. Census Bureau, 2000).

In urbanized coastal settings, from Casco Bay, Maine, through Long Island Sound, wastewater treatment facilities that discharge directly into coastal waters are the major source of anthropogenic nitrogen input. In the Mid-Atlantic, in addition to atmospheric and urban sources, agricultural operations from crops, poultry farms, and manure from other animal operations are important additional sources of nutrients. (Roman et al., 2000) provide a recent and detailed review of the geological history of the Northeast and the effects of human activity along coastal New England. A review of the geologic history and geomorphology of Mid-Atlantic estuaries and subsequent human alterations can be found in Paul (2001).

In New England, successive glacial advances shaped the landscape, soils, and coastline. The major estuaries are former river valleys (Connecticut and Hudson) that were scoured by glaciers and submerged following rapid melting of the most recent large ice sheet between 17,000 and 13,000 years ago. Thicker soils are found in the Mid-Atlantic, due in part to the lack of glacial scouring, and contribute to relatively higher sediment delivery to coastal waters, which reduces the water clarity from New Jersey southward. The resulting reductions in light penetration usually limit seagrass meadows to depths less than 7 feet in Southeast coastal plain estuaries. In contrast, seagrass meadows can exceed 33 feet in depth in the clearer waters of New England (Thayer et al., 1984; Roman et al., 2000). The coastal waters from New York southward are relatively shallow, with samples of marine organisms collected at an average depth of 21 feet, contrasting with an average depth of 57 feet for collection of benthic organisms from the waters from New York northward through Maine.

Woods Hole Yacht Club, Great Harbor at Woods Hole, Massachusetts (Edgar Kleindinst, NMFS Woods Hole Laboratory).

Cape Cod represents a major biogeographic transition area that divides the more boreal waters to the north of Cape Cod (Acadian Province) from the warmer, temperate waters to the south of Cape Cod (Virginian Province) (Figure 3-4). The relatively larger average tidal ranges of 7 to 13 feet in the Acadian Province contribute to greater tidal mixing and flushing, in contrast to the tidal ranges of 7 feet or less in the coastal waters of the Virginian Province. Chesapeake Bay is considered microtidal in character, having average tidal ranges of less than 3 feet (Hammar-Klos and Thieler, 2001).

Chesapeake Bay is the largest estuary in the United States, initially formed as a result of an impact when a bolide (a large extraterrestrial object, such as an asteroid or comet) crashed into shallow seas 35 million years ago (Poag, 1999). Along the western shore of Chesapeake Bay, the Susquehanna, Potomac, and James rivers cut into the side of this crater and currently contribute 80% of the bay's fresh water. As the most recent ice sheet to the north melted, the sea once again entered and flooded former river valleys around the crater's edge (Poag, 1999).

Currently, Chesapeake Bay has a total area of 4,404 square miles, representing 59% of the Northeast Coast water area. The large size and volume of the bay and the relatively small tidal range contribute to a freshwater residence time of 7.6 months, much longer than that of other estuaries in the region (Nixon et al., 1996). In contrast, Delaware Bay, Narragansett Bay, and Boston Harbor have freshwater residence times of 3.3, 0.85, and 0.33 months, respectively (Dettmann, 2001). Because of the size of Chesapeake Bay, conditions heavily influence area-weighted statistical summaries of Northeast Coast conditions.

NCA sampling sites for the Northeast Coast are shown in Figure 3-4. From Delaware northward through Maine, sampling locations are based on probabilistic sampling designs targeting 100% of the coastal waters over a 2-year sampling period. Stations sampled from the 2000 summer field season were included in this analysis and are shown in Figure 3-4. Because these stations are randomly and uniformly distributed throughout the region, they represent the entire area; however, because there were only one-half as many per unit area, their weighting factors were

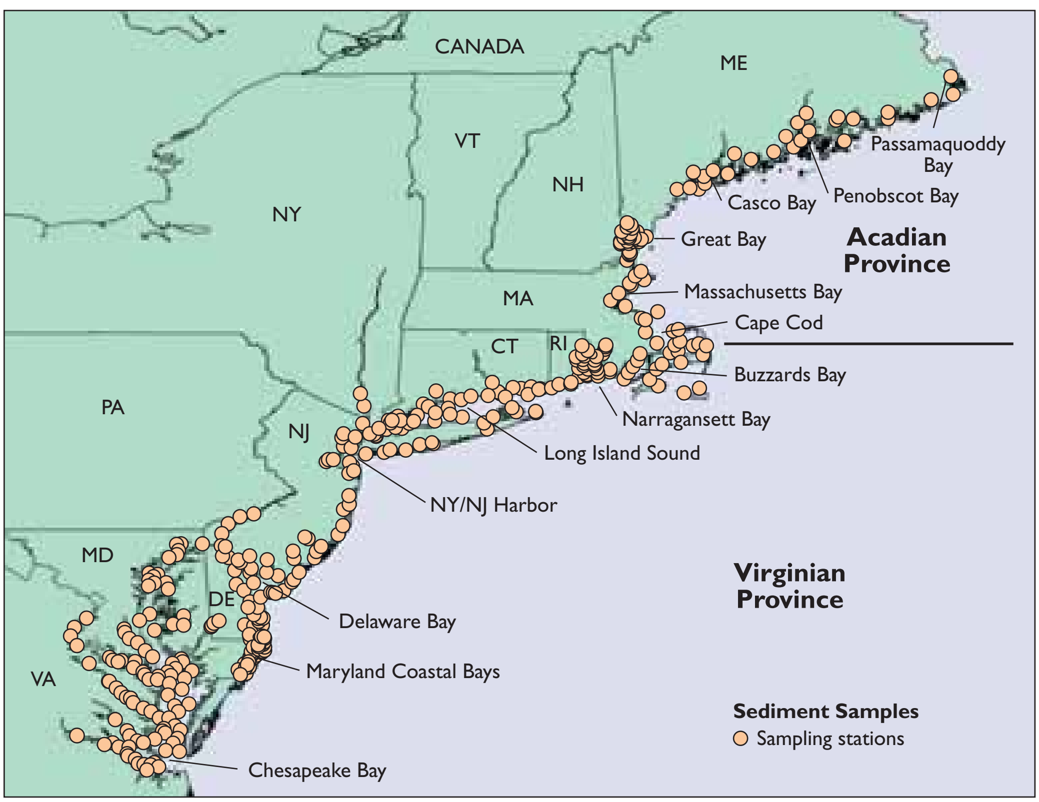


Figure 3-4. Sampling stations on the Northeast Coast used for NCA and Mid-Atlantic Integrated Assessment (MAIA) data (U.S. EPA/NCA).

doubled in calculations. The design of Maryland coastal bays called for 100% sampling of coastal waters in 2000; thus, the weighting factors were not altered. In Chesapeake Bay, the water quality and benthic data measured by the Chesapeake Bay Program in 2000 were used for this analysis. All of the Chesapeake Bay sediment chemistry data and fish tissue contaminant data used in this report are based on the Mid-Atlantic Integrated Assessment (MAIA) 1997 survey (U.S. EPA, 2002).

Several of the coastal states participating in the NCA surveys also have their own separate monitoring networks. For example, New Jersey has shellfish, water quality, and chlorophyll monitoring networks. New Jersey's monitoring networks have a higher density of stations in coastal waters and are monitored at greater frequency than those used in the broad NCA surveys (Baldwin-Brown et al., 2003). These networks are not probabilistically designed, and sites are located largely based on best scientific judgment; however, some sites are essentially placed at random in an area. Some of these random sites have been incorporated in the NCA monitoring design. Such complementary monitoring programs provide essential additional information for the interpretation of time-varying coastal conditions (particularly those that vary over short time scales), as well as provide the additional information needed to document areas of local impairment.

The sampling conducted in the EPA NCA Program has been designed to estimate the percent of estuarine area (nationally or in a region or state) in varying conditions and is displayed as pie diagrams. Many of the figures in this report illustrate environmental measurements made at specific locations (colored dots on maps); however, these dots (color) represent the value of the indicator specifically at the time of sampling. Additional sampling may be required to define variability and to confirm impairment or the lack of impairment at specific locations.

Coastal Monitoring Data

Water Quality Index

The condition of Northeast Coast estuaries as measured by the water quality index is fair to poor. Poor water quality condition was found in 19% of the Northeast Coast estuarine area during the summer of 2000 (Figure 3-5) Most of the stations rated poor were concentrated in a few estuarine systems, in particular New York Harbor, some tributaries of Delaware Bay, the Delaware River, the coastal bays of Maryland and Delaware, and the western and northern tributaries of Chesapeake Bay. Fair condition was observed in 42% of Northeast Coast estuaries. The water quality index indicates that water quality degradation was more prevalent in the coastal waters of the Virginian Province (south of Cape Cod) than in the coastal waters of the Acadian Province (north of Cape Cod), but signs of degraded water quality condition were also noted throughout the Acadian Province. Generally, the relatively open rocky coasts; cold, salty waters; and high tidal ranges of the Acadian Province favor well-mixed conditions that

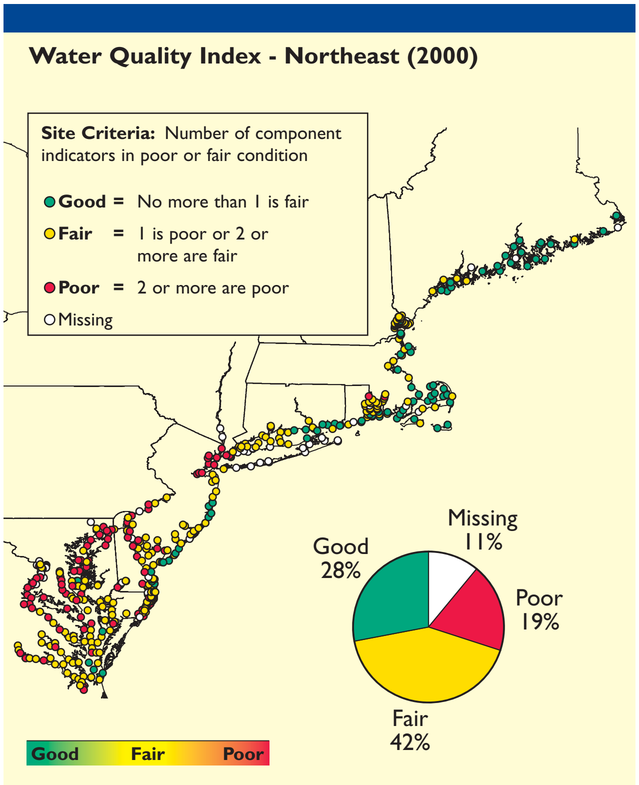


Figure 3-5. Water quality index data for Northeast Coast estuaries (U.S. EPA/NCA).

minimize accumulation of nutrients or organic matter, which lead to the undesirable effects associated with water quality degradation. In contrast, the historically unglaciated parts of the Virginian Province have extensive watersheds to funnel nutrients, sediment, and organic material into secluded, poorly flushed estuaries that are much more susceptible to eutrophication. The pattern of eutrophication also closely reflects the distribution of population density (Figure 3-3).

Further analyses are based on the spatial patterns of the five component indicators used in the NCA water quality index. For local management applications, the results summarized in this report should be interpreted in the context of additional information, such as site-specific criteria and state water quality standards. There are few estuarine water quality standards for nitrogen or chlorophyll *a*. For this regional/national assessment, a single set of guidelines was used throughout the region, except when assessing specific indicators (e.g., water clarity).

Assessing Water Quality Condition in Individual Estuarine Systems

Water quality responses can be complicated and cannot be described by a simple index for all estuarine systems. An index that may work well throughout most of a region may not describe the eutrophic conditions in a specific estuary. For example, Delaware Bay has naturally high concentrations of suspended solids, and DIN concentrations remained high during the sampling period when phytoplankton production was light-limited. Water quality degradation in much of the open portion of Delaware Bay is not considered to be a problem in late summer. In this report, selected tributaries of Delaware Bay and many parts of the Delaware River received poor ratings on the water quality index for specific sites, whereas open water areas in the Delaware Bay received fair or good ratings. For such local situations, less weight could be given to nutrient concentrations measured in late summer and greater weight to phytoplankton production (chlorophyll *a*) or dissolved oxygen concentrations. The water quality index used in this report is intended for regional and national assessments and may not be suitable for every individual estuary. Indicators that account for local ecological conditions may need to be measured, in addition to the standard set of NCA indicators, to provide a better picture of water quality in certain estuarine systems. The NCA data used for the national and regional assessments in this report are of known quality and can be queried using different weighting factors and indicator combinations that may be more representative of specific estuary conditions.

Nutrients: Nitrogen and Phosphorous

Figures 3-6 and 3-7 show the concentration ranges of DIN and DIP in surface waters in the Northeast Coast. From a regional perspective, the overall rating for DIN is fair (11% of the estuarine area is in poor condition), and the overall rating for DIP is good (5% of the estuarine area is in poor condition). DIP is more likely to promote algal growth in tidal-fresh parts of estuaries, whereas DIN is the nutrient type most responsible for eutrophication in open estuarine and marine waters. The highest nutrient concentrations in the Northeast Coast were found in New York Harbor and Maryland coastal bays, Narragansett Bay (Rhode Island), and several tributaries in the Chesapeake and Delaware estuaries. Fair to poor conditions were measured in Delaware Bay, Narragansett Bay, and Great Bay (New Hampshire). Good conditions were notable in the Chesapeake mainstem, Long Island Sound (for DIN), and much of the Acadian Province. Thus, even during the late-summer NCA sampling period, up to 38% of the Northeast Coast had moderate to high levels of nutrients.

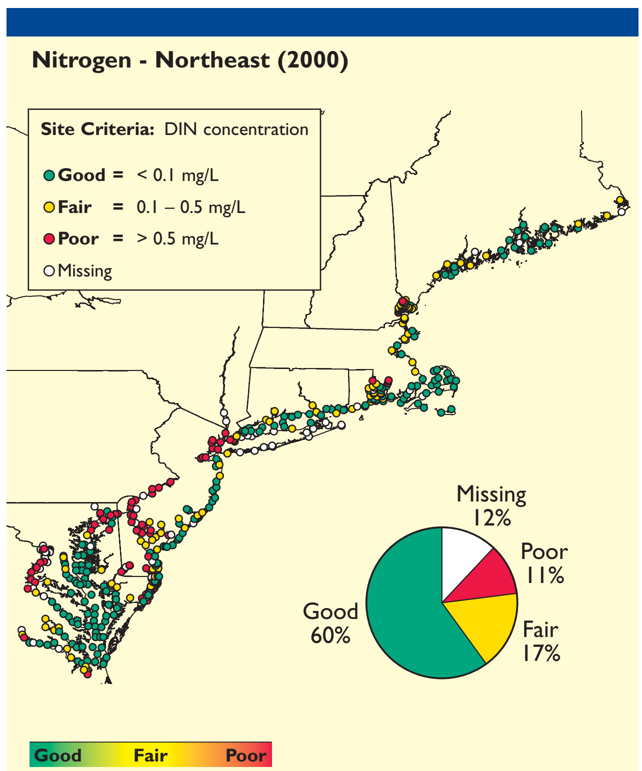
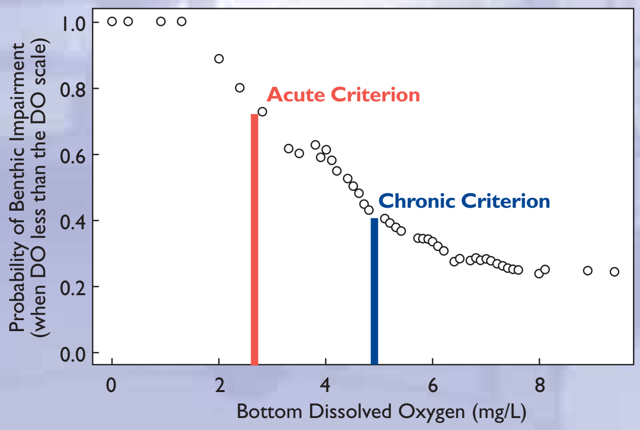


Figure 3-6. DIN concentration data for Northeast Coast estuaries (U.S. EPA/NCA).

highlight

Benthic Condition in Chesapeake Bay Declines When Dissolved Oxygen Declines

Changes in the number and types of benthic macroinvertebrate communities (BMC) can help document ecological conditions. Degraded BMCs often have lower species diversity and can include opportunistic species that occur in great abundance. BMC data can be summarized using a BMC index (Paul et al., 2001), which is designed to discriminate between healthy and degraded sites within a region or state. BMC index variations can be analyzed in relation to known stressors (e.g., the probability of degraded benthic conditions in relation to low dissolved oxygen in bottom waters). Using data collected from 1990 to 1993 from the open waters of Chesapeake Bay, there is an increasing probability of BMC impairment (BMC index values <0) at sites with progressively lower dissolved oxygen concentrations. The EPA acute and chronic criteria for dissolved oxygen shown below are based on independent laboratory testing with marine organisms (U.S. EPA, 2000a). This laboratory versus field survey comparison provides some confidence in the validity of the BMC index.



Chesapeake Bay 1990–1993 Virginian Province Data, large systems (Paul et al., 2000).

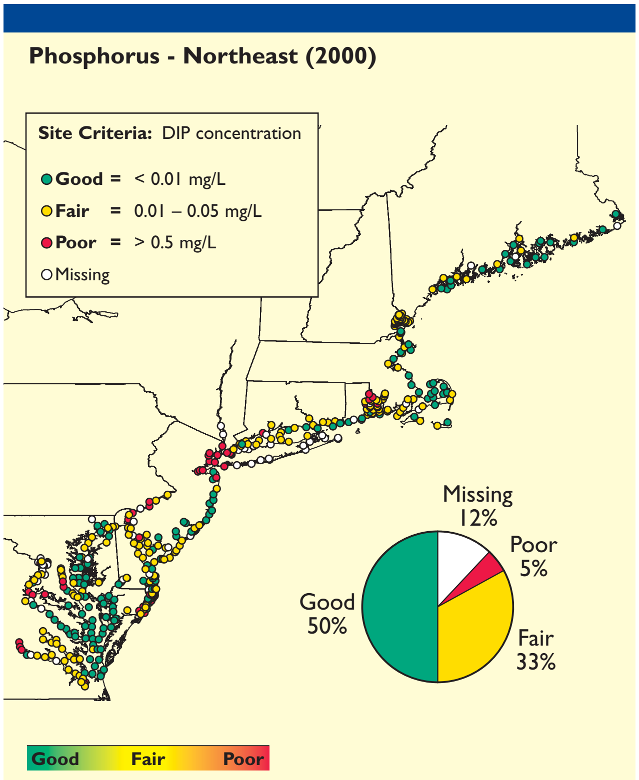


Figure 3-7. DIP concentration data for Northeast Coast estuaries (U.S. EPA/NCA).

Fishing boats in the harbor at Smith Island, Chesapeake Bay, Maryland (Mary Hollinger, NODC biologist, NOAA).

Chlorophyll *a*

The concentration of the plant pigment chlorophyll *a* is used to estimate the quantity of algae suspended in the surface water. About 15% of estuarine area in the Northeast Coast is rated poor for this indicator, which results in an overall rating of fair for chlorophyll in the region (Figure 3-8). Generally, the broad pattern of pigment concentration is similar to that of nutrients, with concentration much higher to the south of Cape Cod than to the north. Chlorophyll *a* concentrations mirror nutrient levels in the Maryland coastal bays, Chesapeake tributaries, and much of the Northeast Coast coastal waters; however, there is little apparent spatial correlation between chlorophyll *a* and nutrients in the Chesapeake mainstem, Delaware Estuary, or New York Harbor region. Spatial patterns in nutrient levels and chlorophyll *a* differ for a number of reasons. One reason is that algae may not be able to use nutrients effectively in very turbid water (e.g., in low-light environments, such as the Delaware Bay) or in regions with high flushing rates. As a result of nutrient uptake by phytoplankton blooms, dissolved nutrients may be low. Locations of peak nutrient and biomass concentrations may coincide in space or time.

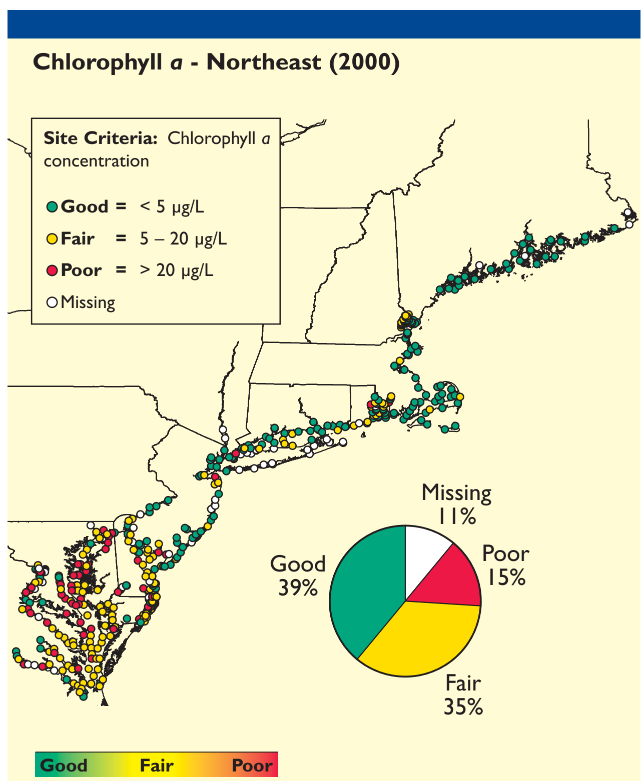


Figure 3-8. Chlorophyll *a* concentration data for Northeast Coast estuaries (U.S. EPA/NCA).

1937 Delaware Statewide Aerial Photography

The ability to assess land use changes over time is a valuable tool for resource managers. Altered shorelines, urban and suburban sprawl, reductions in agricultural acreage, and changes in habitat types are just some land use issues that concern resource managers. In an effort to trace such land use changes, planners in the state of Delaware will soon be able to visually compare current aerial views of the state with historic photos from more than 60 years ago .

Delaware Coastal Programs, in a cooperative effort with the state's Natural Heritage Program, Natural Areas Program, and Forest Service, is undertaking a project that will assist in identifying land use changes by compiling a complete aerial image of the state as it looked in 1937. By comparing these photographs to ones taken in 1997, resource managers will be able to review a 60-year timeframe within which to assess land use changes.

For this project, approximately 700 aerial images of Delaware taken in 1937 were obtained from the National Archives. These photographs were scanned and georeferenced to Delaware State Plane Coordinates, North American Datum 83 meters using ERDAS IMAGINE software. Spatially referenced mosaics were created for each of Delaware's three counties, and any distorted edges, fiducial marks, and photograph borders were cropped. These mosaics enable comparative analysis with existing 1997 statewide Digital Ortho-Quarter Quads. Geographic information systems (GIS) technologies were utilized to identify land use changes.

One analysis currently underway involves evaluating changes in forest cover. In Delaware, older-growth forests are one of the most biologically diverse habitat communities. For the purpose of this effort, older-growth forests are defined as areas that have not been clear cut for 50 years or more. The forest canopy, canopy gaps, and understory of these areas harbor a high number of state-listed rare and endangered species when compared to most upland habitat areas.

To better assess valuable older-growth habitats, forested areas in the 1937 photos were on-screen digitized using ArcGIS software. This coverage will be converted to a grid that can be directly compared with recent photos using spatial analysis techniques to ascertain the location and extent of forest area in 1997 that also existed in 1937. These locations will be used to determine the most likely areas of historic forests. Upon field verification, this information will enable planners and resource managers to prioritize and strengthen conservation efforts of these critical habitats.

Planned future projects include habitat trends and beach extent analysis. Other potential projects using 1937 imagery are also under development.

Coastal Water Quality in New England

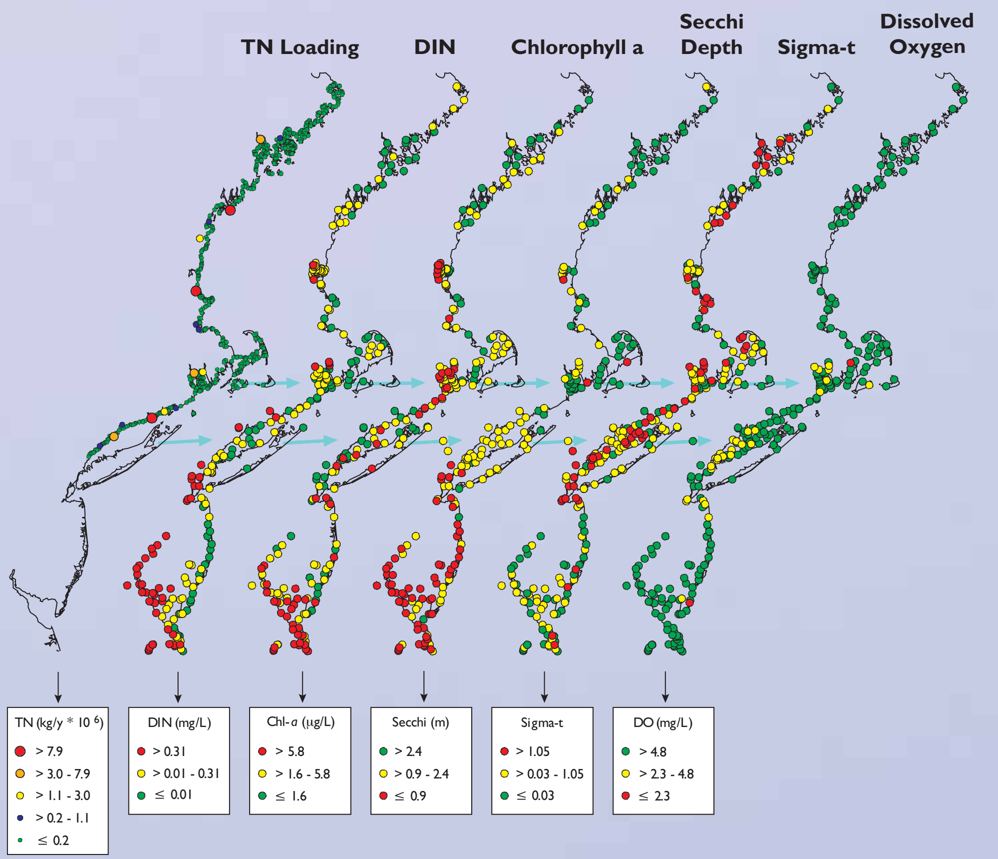
Cooperating state programs have, for the first time, collected and documented regional gradients in New England coastal waters using a consistent set of indicators. Gradients for most of the water quality variables were ranked in the highest 25% (upper quartile), the middle 50%, and the lowest 25% (lower quartile). The figure of coastline traces shown on the following page ranks DIN (sum of nitrate, nitrite, and ammonia), phytoplankton pigment (chlorophyll *a*), light transparency (Secchi depth), water column stratification (delta Sigma-t), and dissolved oxygen with water quality through the use of colored dot markers. These coastal water conditions are based on samples collected in the summer and fall of 2000. Annual Total Nitrogen (TN) loading estimates come from the New England Sparrow model and are based on conditions in the early 1990s. These estimates are shown in the left-most coastline trace on the figure.

Excess nutrient loading can contribute to elevated water column nutrient concentrations, higher levels of phytoplankton pigments, and reduced transparency to light. The red dots indicate data in the upper 25% for DIN and chlorophyll *a*. In contrast, red dots illustrate the lower quartile for light transparency.

When lighter freshwater floats on top of denser saline water, the water column is stratified. In such a water column, the mixing of oxygen to depth is diminished. The red dots indicating surface to bottom water column density difference (delta Sigma-t) illustrate the degree of stratification, with sampling locations falling in the upper 25% (most stratified) colored in red and the lower 25% (least stratified) colored in green. In a well-mixed water column, stratification is absent, and oxygen can be transported from the surface to water at deeper depths.

The far right coastline trace illustrates regional gradients in the dissolved oxygen content of water sampled near the bottom of the water column. Marine water quality criteria for dissolved oxygen are used to define the dot colors. Oxygen concentrations that fall below the EPA acute criterion level of 2.3 mg/L are illustrated with red dots. Yellow dots are used to represent the locations where oxygen concentrations were higher than the acute level, but less than or equal to the EPA chronic criterion level of 4.8 mg/L (U.S. EPA, 2000a).

Regional scale gradients in dissolved oxygen can be noted in these coastline traces. In the Acadian Province north of Cape Cod, dissolved oxygen concentrations measured during the summer 2000 NCA survey were consistently greater than 4.8 mg/L. Water temperatures in the Acadian Province are relatively cold, and consequently, the water holds more oxygen. Tidal ranges are usually greater than 2 meters, promoting increases in tidal currents and an increased mixture of oxygen from the surface to depth. Waters are warmer south of Cape Cod, with tidal ranges less than 2 meters resulting in reduced tidal currents, and consequently, a decreased mixture of oxygen from the surface to depth than locations farther north. Dissolved oxygen concentrations fall below 4.8 mg/L for some of the bottom waters in the area south of Cape Cod, including upper Narragansett Bay, western Long Island Sound, and along the New Jersey shore. Oxygen concentrations persistently below this chronic dissolved oxygen criterion can adversely impact sensitive marine organisms (Coiro et al., 2000).



Source: Moore et al., 2004

Water Clarity

Poor water clarity may be attributed to a number of sources, including suspended sediments, organic material (especially living or dead algae), and dissolved tannins. Estuaries are naturally turbid environments. Turbid waters supply building material for maintaining estuarine structures and provide food and protection to resident organisms; however, the extensive particle loads of turbid waters are harmful if they bury benthic communities, inhibit filter feeders, or block light needed by seagrasses. Because 23% of the Northeast Coast estuarine area has poor water clarity, the overall rating for the region is fair (Figure 3-9).

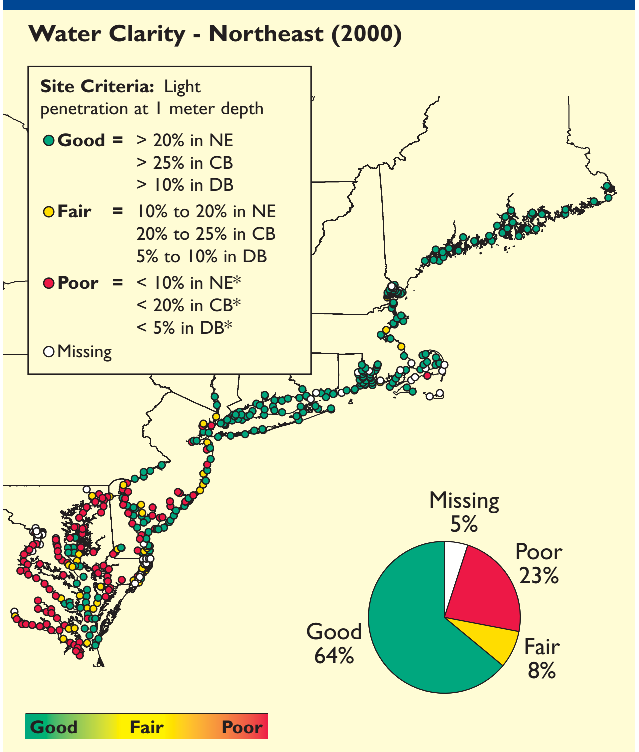


Figure 3-9. Water clarity condition for Northeast Coast estuaries (U.S. EPA/NCA). *NE represents sampling sites in the Northeast Coast region except for those sites located in Chesapeake Bay (CB) or Delaware River/Bay (DB).

Estuarine Systems	Reference Condition for Water Clarity (Percentage of Incident Light Reaching 1 Meter in Depth)
Chesapeake Bay system	20%
Delaware River/Bay system	5%
All remaining Northeast Coast estuarine systems	10%

Large mussels dot the shoreline at Edgar M. Tennis Preserve, Deer Isle, Maine (Captain Albert E. Theberge, NOAA Corps, ret.).

Dissolved Oxygen

The final indicator for the water quality index is the concentration of dissolved oxygen measured 1 meter above the sediment. This indicator is rated fair for Northeast Coast estuaries. Oxygen levels may become depleted in isolated bottom regions when excess organic material sinks and decays, especially if the water column is stratified. Most states use 5 mg/L of dissolved oxygen as the criterion for designating unacceptable water quality. Sensitive organisms can tolerate dissolved oxygen concentrations below 2 mg/L (hypoxia) for only a few days before dying. Hypoxia (and often anoxia) was evident in 10% of the Northeast Coast estuarine area, almost exclusively in the deep, isolated trenches of the Chesapeake mainstem (Figure 3-10). Fair conditions (2–5 mg/L dissolved oxygen) were measured in another 18% of the region, notably in the Chesapeake Bay, Long Island Sound, and Narragansett Bay. Dissolved oxygen levels were acceptable in two-thirds of Northeast Coast estuarine area. The areal extent of low dissolved oxygen in larger estuarine systems in 2000 may have been reduced by drought, which leads to reduced freshwater and nutrient input (e.g., Chesapeake Bay, Long Island Sound).

Temporal variations in dissolved oxygen depletion can have adverse biological effects (Coiro et al., 2000). Stressful hypoxia may occur for a few hours before dawn in productive surface waters, when respiration depletes dissolved oxygen faster than it is replenished. The NCA Program does not measure these events because most samples are taken later in the day. As a result of a variety of factors, year-to-year variations in dissolved oxygen in estuaries can be substantial, including variations in freshwater inflow, factors affecting water column stratification, and changes in nutrient delivery. A recent review of factors affecting the extent of hypoxic bottom water in Chesapeake Bay can be found in Hagy (2002) and Hagy et al. (2004). The Highlight "Use of a Hybrid Monitoring Design in Rhode Island," found at the end of this chapter, focuses on temporal variations in oxygen depletion in upper Narragansett Bay, which are modulated by predictable variations in tidal range. In the summer of 2000, the NCA survey detected dissolved oxygen concentrations below 5 mg/L (yellow dots in Figure 3-10). More intensive and complementary monitoring programs in upper Narragansett Bay documented episodic dissolved oxygen depletion events (dissolved oxygen <2 mg/L) during short time periods. These short-duration events can be accompanied by fish kills.

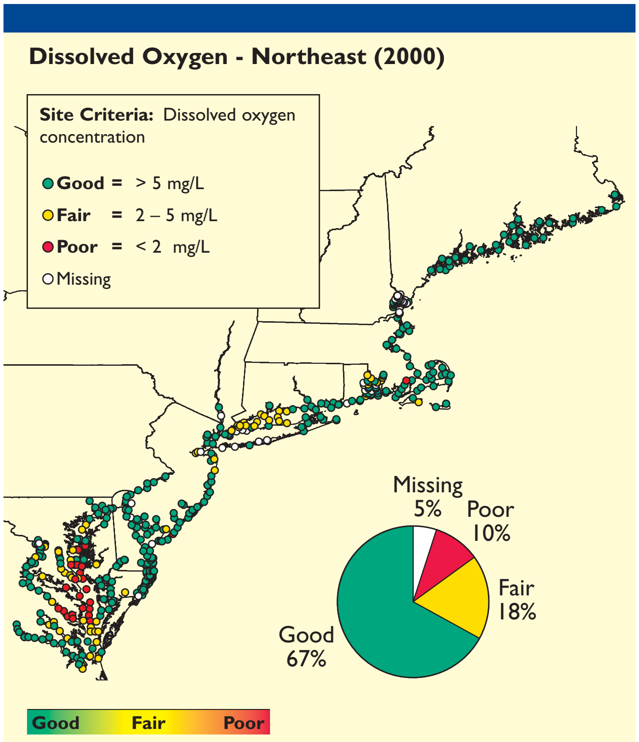


Figure 3-10. Dissolved oxygen concentration data for Northeast Coast estuaries (U.S. EPA/NCA).

Sediment Quality Index

Sediment condition as measured by the sediment quality index in Northeast Coast estuarine areas is rated poor. Sixteen percent of Northeast Coast estuarine sediments received a poor rating (Figure 3-11), meaning that at least one of the component indicators (sediment toxicity, sediment contaminants, or sediment TOC) at each of the sites received a poor rating. Regions that are relatively unimpaired include the Acadian Province (other than Great Bay, New Hampshire), eastern Long Island Sound, and the open regions of the Delaware and Chesapeake bays.

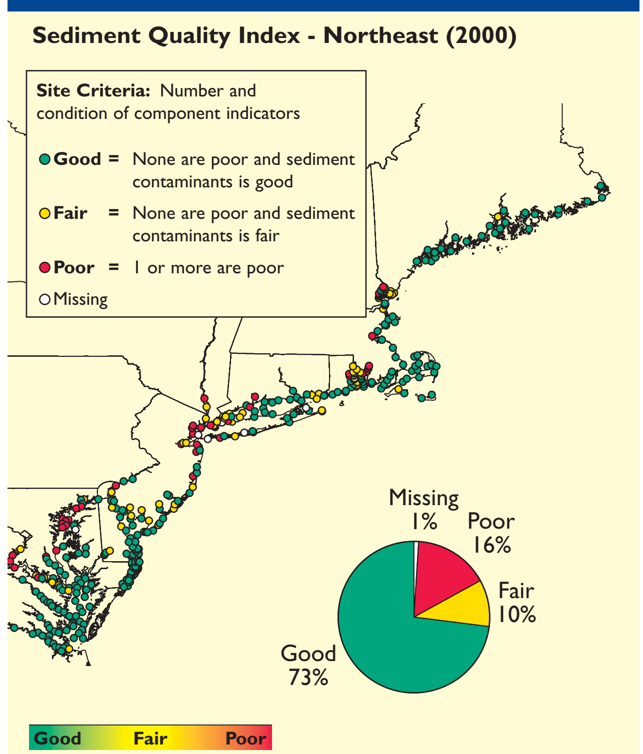


Figure 3-11. Sediment quality index data for Northeast Coast estuaries (U.S. EPA/NCA).

Portsmouth area, New Hampshire (Mr. Sean Linehan, NOAA, NGS, Remote Sensing).